

What is claimed is:

1. A fiber-metal laminate comprising: at least two metallic layers and at least one fiber layer disposed between the metallic layers; wherein the fiber layer contains a resin matrix and organic polymeric fibers having a modulus of elasticity of at least 270 GPa.

5 2. The laminate of Claim 1, wherein the polymeric fibers are electrically substantially non-conducting.

3. The laminate of Claim 1, wherein the polymeric fibers are not galvanically reactive with the metallic layers.

10 4. The laminate of Claim 1, wherein the polymeric fibers include poly diimidazo pyridinylene fibers.

5. The laminate of Claim 4, wherein the poly diimidazo pyridinylene fibers include poly {2,6-diimidazo [4,5-b4',5'-e] pyridinylene-1,4(2,5-dihydroxy) phenylene} fibers.

6. The laminate of Claim 1, wherein the at least two layers include an aluminum alloy.

15 7. The laminate of Claim 1, wherein the aluminum alloy includes a heat treatable aluminum alloy.

8. The laminate of Claim 1, wherein the at least two layers include a titanium alloy.

9. The laminate of Claim 1, wherein the at least two layers include a stainless steel alloy.

10. The laminate of Claim 1, wherein the resin matrix includes an epoxy resin.

20 11. The laminate of Claim 1, wherein the at least two metallic layers constitute no more than 40 percent by weight of the laminate.

12. The laminate of Claim 1, wherein the at least two metallic layers constitute at least 10 percent and no more than 50 percent by volume of the laminate.

25 13. The laminate of Claim 1, wherein at least 90 percent of the fibers are substantially aligned in one direction.


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14. The laminate of Claim 13, wherein about 100 percent of the fibers are aligned in the substantially same direction.

15. The laminate of Claim 1, wherein at least 10 percent of the fibers are aligned at a first direction 45° from a second direction to which at a majority of the fibers are aligned.

5 16. The laminate of Claim 1, wherein the at least a portion of the fibers are aligned in a plurality of directions.

17. The laminate of Claim 1, wherein the fibers include continuous fibers.

18. The laminate of Claim 1, which contains at least 3 and no more than 15 metallic layers.

10 19. The laminate of Claim 1, wherein the at least one fiber layer includes between 3 and 15 plies of fibers.

20. The laminate of Claim 1, wherein the at least two metallic layers each have a thickness of at least 0.004 inch and no more than 0.025 inch.

15 21. The laminate of Claim 1, wherein the surfaces of the metallic layers are pre-treated by phosphoric acid anodizing.

22. The laminate of Claim 1 wherein the surfaces of the metallic layers are pre-treated by coating with an interphase layer.

23. The laminate of Claim 22, wherein the interphase layer includes a sol-gel surface preparation.

20 24. The laminate of Claim 1 which additionally comprises a layer of an adhesive resin between the fiber layer and the metallic layers, wherein the adhesive resin is different from the resin matrix.

25. The laminate of Claim 24 wherein the adhesive includes an epoxy adhesive.

25 26. The laminate of Claim 1, further comprising at least one core layer disposed between the at least two metallic layers.

27. The laminate of Claim 26, wherein the core layer includes a honeycomb core.

28. A fiber-metal laminate comprising:
at least two layers of aluminum alloy; and
at least one resin-fiber ply bonded between the aluminum alloy layers, the ply
5 including a resin matrix and poly diimidazo pyridinylene fibers.

29. The laminate of Claim 28, wherein the poly diimidazo pyridinylene fibers include
poly {2,6-diimidazo [4,5-b4',5'-e] pyridinylene-1,4(2,5-dihydroxy) phenylene} fibers.

30. The laminate of Claim 28, wherein the aluminum alloy includes a heat treatable
aluminum alloy.

10 31. The laminate of Claim 28, wherein the resin-fiber ply is bonded between the
aluminum alloy layers with an adhesive resin different from the matrix resin.

32. The laminate of Claim 28, wherein the resin matrix includes an epoxy resin.

33. The laminate of Claim 28, wherein the metallic layers constitute less than 40
percent by weight of the laminate.

15 34. The laminate of Claim 28, wherein the at least two metallic layers constitute
between 10 percent and 50 percent by volume of the laminate.

35. The laminate of Claim 28, wherein at least 90 percent of the fibers are substantially
aligned in one direction.

20 36. The laminate of Claim 35, wherein about 100 percent of the fibers are aligned in the
substantially same direction.

37. The laminate of Claim 28, having at least 3 and no greater than 15 metallic layers.

38. The laminate of Claim 28, wherein the at least one fiber layer includes between 3
and 15 layers of aligned polymer fibers.

25 39. The laminate of Claim 28, wherein the metallic layers each have a thickness of at
least 0.004 inch and 0.025 inch.

40. The laminate of Claim 28, wherein the surfaces of the metallic layers are pre-treated
by phosphoric acid anodizing.

41. The laminate of Claim 28 wherein the surfaces of the metallic layers are pre-treated by coating with an interphase layer of resin.

42. The laminate of Claim 28, wherein the surfaces of the metallic layers are pre-treated with a sol-gel surface preparation.

5 43. The laminate of Claim 28, further comprising at least one hollow core layer disposed between the at least two metallic layers.

44. The laminate of Claim 43, wherein the hollow core layer includes a honeycomb core.

45. A composite aircraft component comprising:
10 at least two aluminum alloy foil layers each having a thickness in a range from 0.004 inches to 0.025 inches; and
at least one polymeric composite layer bonded between the at least two foil layers, the composite layer including a resin matrix and aligned poly diimidazo pyridinylene fibers.

15 46. The laminate of Claim 45, wherein the poly diimidazo pyridinylene fibers include poly {2,6-diimidazo [4,5-b4',5'-e] pyridinylene-1,4(2,5-dihydroxy) phenylene} fibers.

47. The laminate of Claim 45, wherein the resin matrix includes an epoxy resin.

48. The laminate of Claim 45, wherein the at least two metallic layers constitute no more than 40 percent by weight of the laminate.

20 49. The laminate of Claim 45, wherein the at least two metallic layers constitute at least 10 percent and no greater than 50 percent by volume of the laminate.

50. The laminate of Claim 45, wherein greater than 90 percent of the fibers are substantially aligned in one direction.

25 51. The laminate of Claim 45, wherein about 100 percent of the fibers are substantially aligned in one direction.

52. The laminate of Claim 45, wherein at least 10 percent of the fibers are aligned in a first direction 45° to a second direction a majority of the remaining fibers are aligned.

53. The laminate of Claim 45, wherein the at least a portion of the fibers are aligned in a plurality of different directions.

54. The laminate of Claim 45, wherein at least two final layers include at least 3 and no greater than 15 foil layers.

5 55. The laminate of Claim 45, wherein the at least one polymeric composite layer includes at least three 3 and no more than 15 polymeric composite layers.

56. A method for producing a fiber-metal laminate, the method comprising:
providing a plurality of metallic layers;
aligning a plurality of polymer fibers having a modulus of elasticity of greater than
10 270 GPa into at least one fiber layer; and
sandwiching the at least one fiber layer between the plurality of metallic layers.

57. The method of Claim 56, further comprising bonding the at least one high modulus
fiber layer to the plurality of metallic layers adjoining the high modulus fiber layer using an
15 adhesive resin different from the matrix resin.

58. The method of Claim 56, further comprising pretreating the plurality of metallic
layers.

59. The method of Claim 58, wherein pretreating includes pretreating with a sol-gel
coating.

20 60. The method of Claim 56, wherein the poly diimidazo pyridinylene fibers include
poly {2,6-diimidazo [4,5-b4',5'-e] pyridinylene-1,4(2,5-dihydroxy) phenylene} fibers.

61. The method of Claim 56, wherein the plurality of metallic layers include an
aluminum alloy.

25 62. The method of Claim 56, wherein the plurality of metallic layers include a titanium
alloy.

63. The method of Claim 56, wherein the plurality of metallic layers include a stainless
steel alloy.

64. The method of Claim 56, wherein the resin matrix includes an epoxy resin.

65. The method of Claim 56, wherein the at least two metallic layers constitute less than 40 percent by weight of the laminate.

66. The method of Claim 56, wherein the at least two metallic layers constitute between 10 percent and 50 percent by volume of the laminate.

5 67. The method of Claim 56, further comprising forming a hollow core between the plurality of metallic foil layers.

68. The method of Claim 67, wherein forming a hollow core includes forming a honeycomb core.

10 69. A fiber-metal laminate produced according to a method comprising:
providing a plurality of metallic layers;
aligning a plurality of polymer fibers having a modulus of elasticity of greater than 270 GPa into at least one fiber layer; and
sandwiching the at least one fiber layer between the plurality of metallic layers.

15 70. The laminate of Claim 69, produced according to the method further comprising bonding the at least one high modulus fiber layer to the plurality of metallic layers adjoining the high modulus fiber layer.

71. The laminate of Claim 69, produced according to the method further comprising pretreating the plurality of metallic layers.

20 72. The method of Claim 71, wherein pretreating includes pretreating with a sol-gel coating.